United States Patent [19]

Drewes et al.

[11] **4,349,898**

[45] **Sep. 14, 1982**

[54] **SONIC WEAPON SYSTEM**

[75] Inventors: **William Drewes**, 100 Ellison Ave., Bronxville, N.Y. 10708; **Edward M. Vlicki**, Elmwood Park, N.J.

[73] Assignee: **William Drewes**, Bronxville, N.Y.

[21] Appl. No.: **959,302**

[22] Filed: **Nov. 9, 1978**

[51] **Int. Cl.**[3] **H04B 1/02**

[52] **U.S. Cl.** **367/138**; 367/92; 367/139

[58] **Field of Search** 367/92, 137, 138, 139

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,612,211 10/1971 Clark ..... 367/139 X
3,613,069 10/1971 Cary, Jr. et al. 367/92

OTHER PUBLICATIONS

Rudenko et al., "TheoreticalFoundations of Nonlinear Acoustics", (English Translation) Consultant's Bureau, New York, 1977, pp. 145–147.

Primary Examiner—Richard A. Farley
Attorney, Agent, or Firm—Hubbell, Cohen, Stiefel & Gross

[57] **ABSTRACT**

A system for transmitting a parametrically pumped sonic signal through a transmission medium to a remote location is disclosed. The preferred system, which is particularly intended for use as a sonic weapon, comprises a sound source; means for separating the sound into a plurality of discrete frequency components including a fundamental component and at least one additional component, each additional component having a frequency twice that of the next lowest frequency component; means for adjusting the phase difference between each frequency component and the next lowest frequency component to substantially 90°; means for colinearly focusing the components on the remote location; and means for rendering the transmission medium nonlinear between the focusing means and the remote location.

36 Claims, 11 Drawing Figures

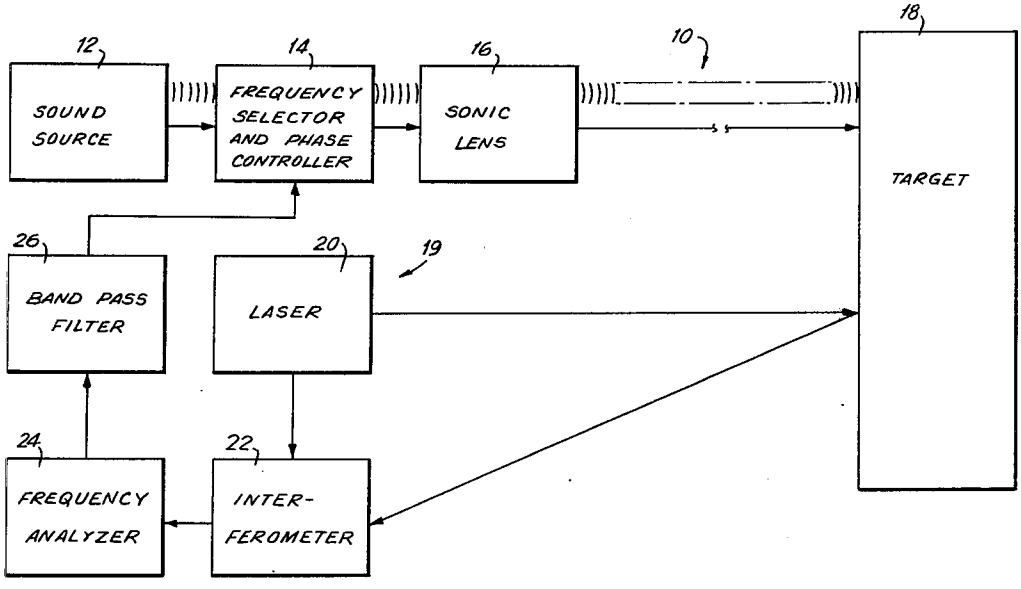


FIG. 1

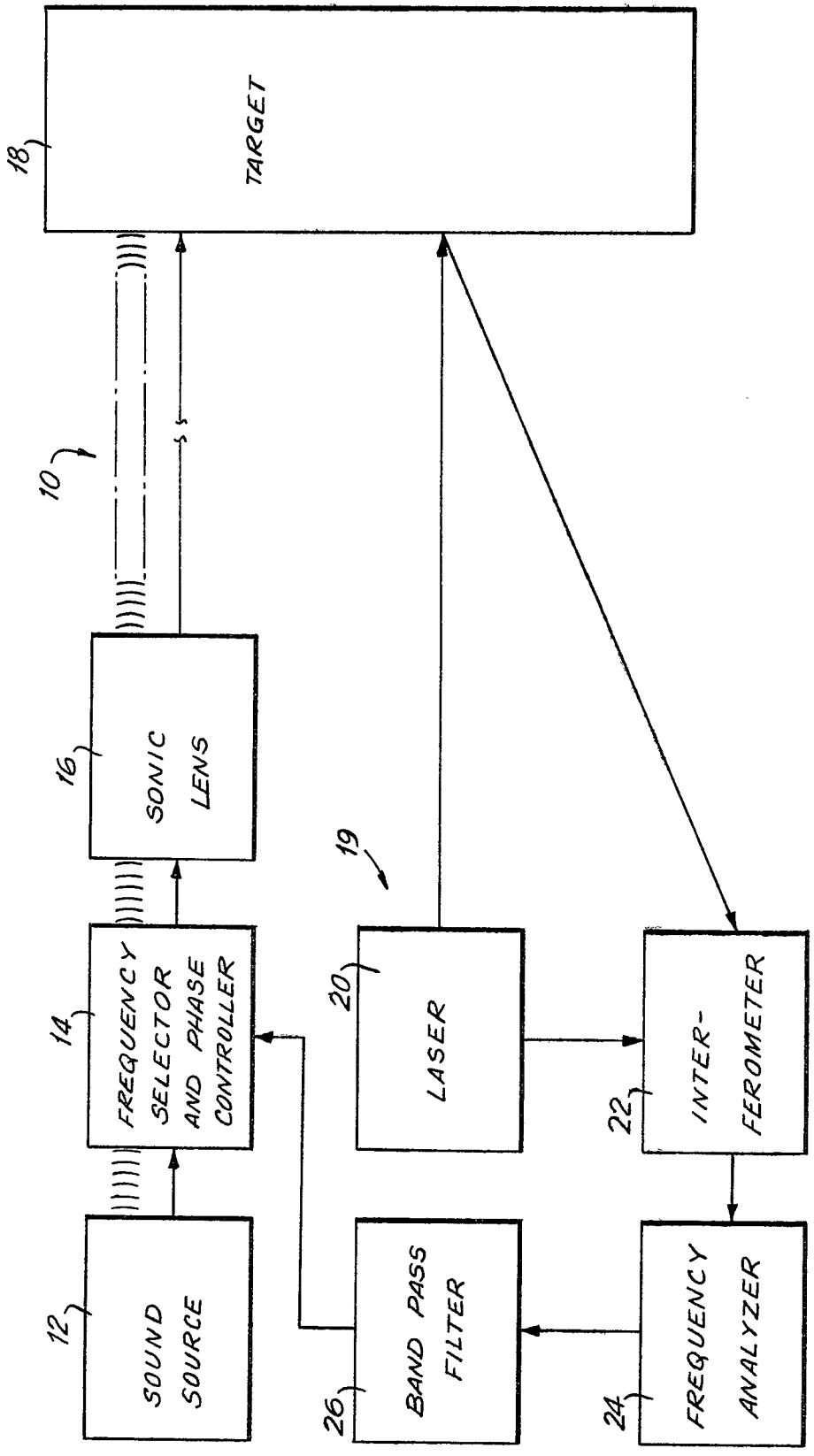

TARGET
18
10
SONIC LENS
16
19
FREQUENCY SELECTOR AND PHASE CONTROLLER
14
LASER
20
INTER-FEROMETER
22
SOUND SOURCE
12
BAND PASS FILTER
26
FREQUENCY ANALYZER
24

FIG. 2A

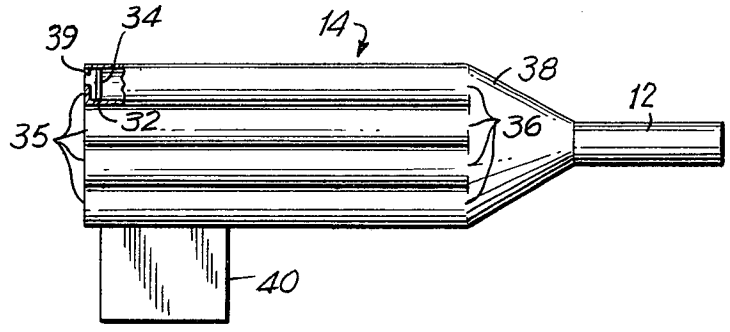


FIG. 2B

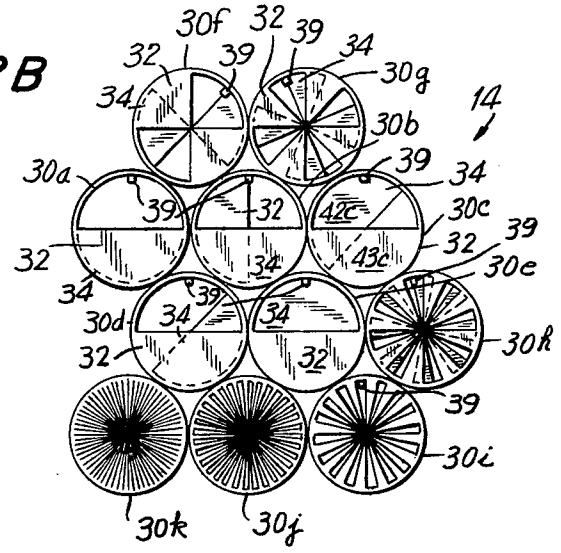


FIG. 3A

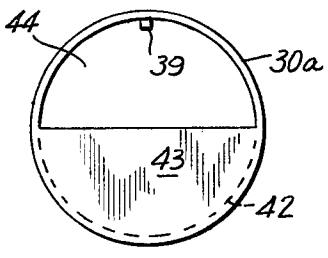


FIG. 3B

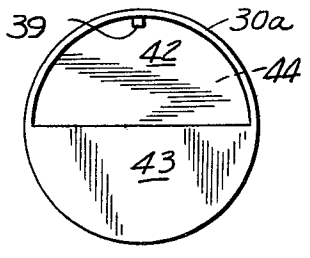


FIG. 4

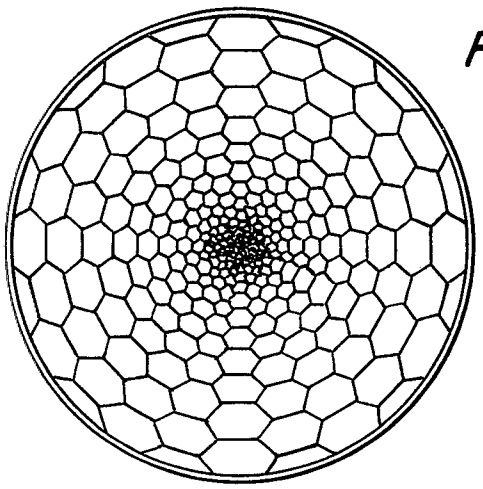


FIG. 5

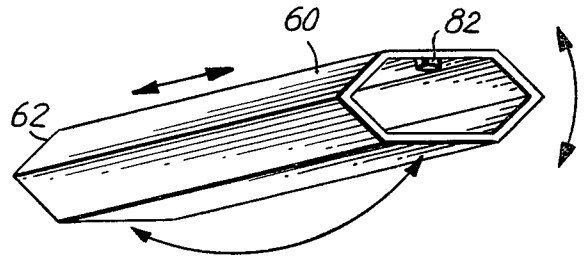


FIG. 8

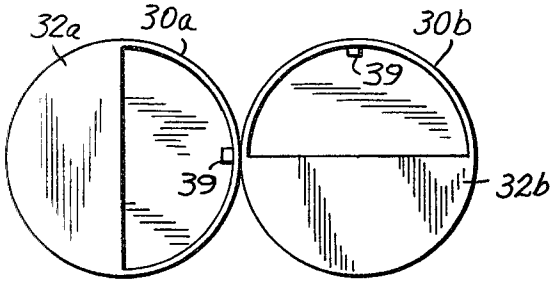
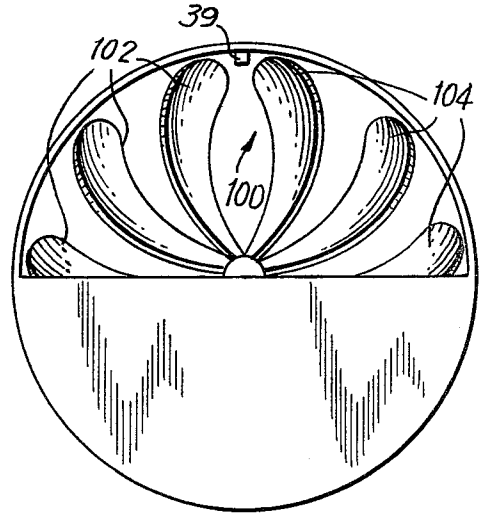


FIG. 9



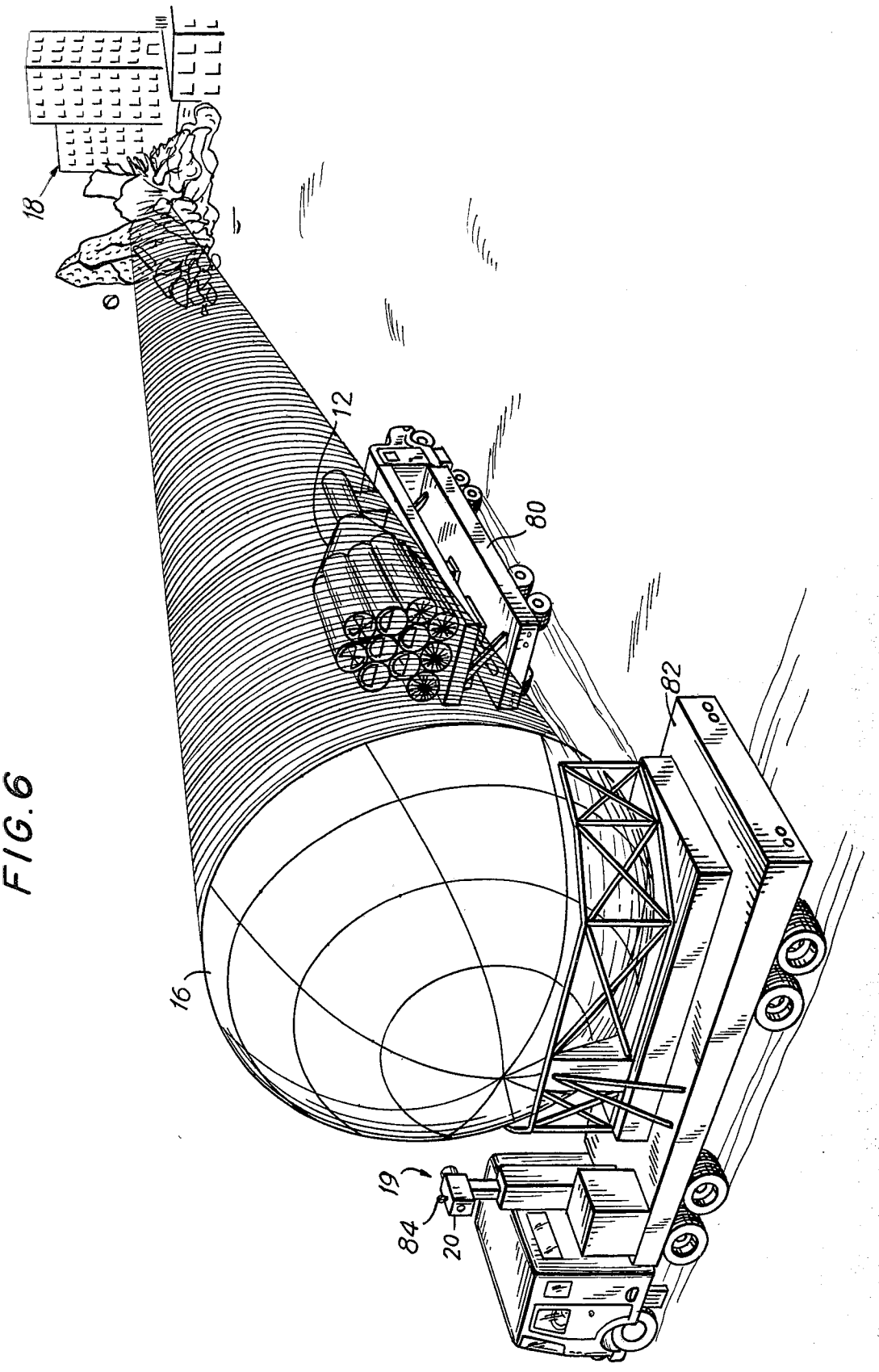
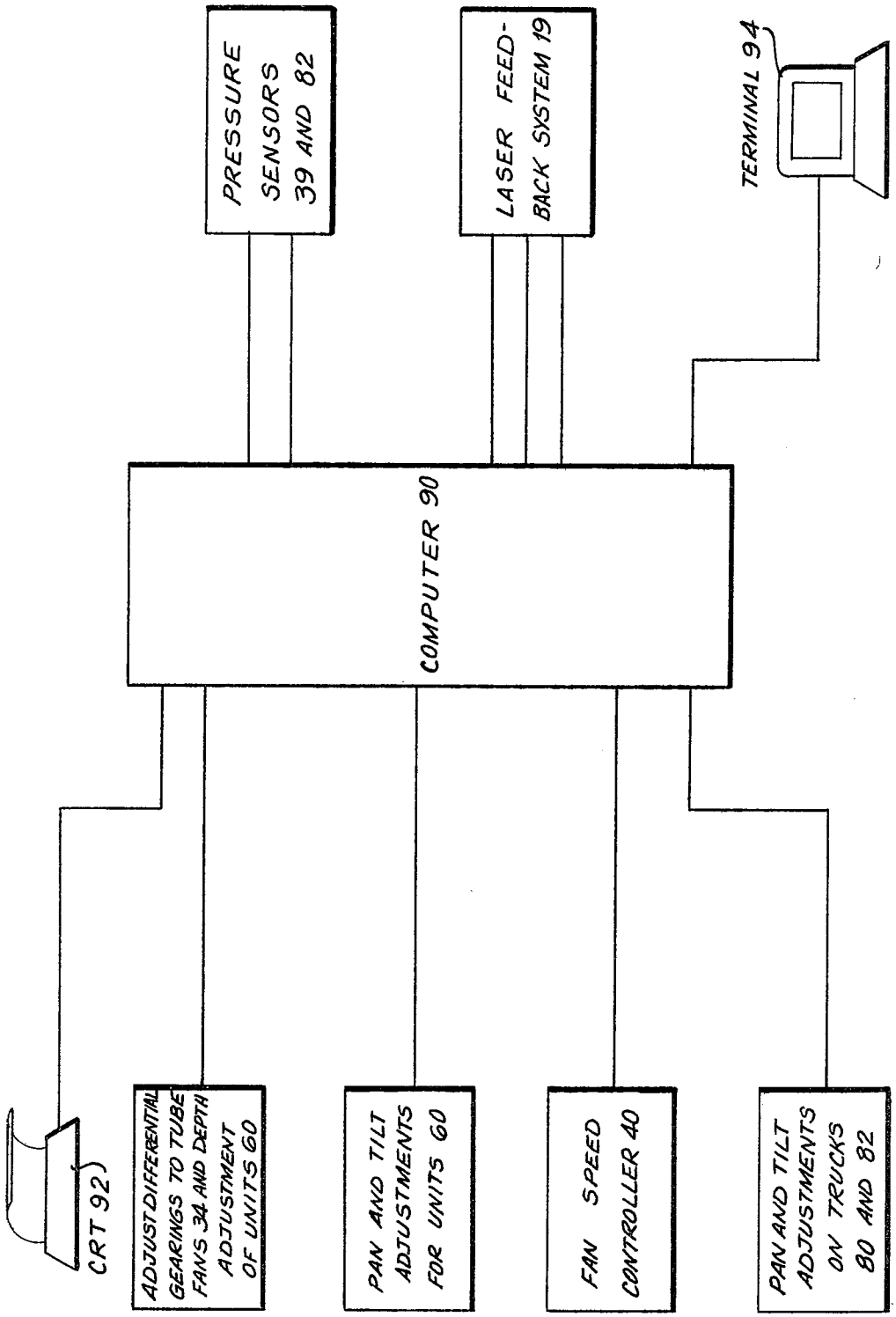


FIG. 6

FIG. 7


PRESSURE SENSORS 39 AND 82
LASER FEED-BACK SYSTEM 19
TERMINAL 94
COMPUTER 90
CRT 92
ADJUST DIFFERENTIAL GEARINGS TO TUBE FANS 34 AND DEPTH ADJUSTMENT OF UNITS 60
PAN AND TILT ADJUSTMENTS FOR UNITS 60
FAN SPEED CONTROLLER 40
PAN AND TILT ADJUSTMENTS ON TRUCKS 80 AND 82

SONIC WEAPON SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention pertains to sonic transmission systems and more particularly to systems for transmitting low frequency sonic signals with long range characteristics. Most particularly, this invention pertains to a parametrically pumped sonic weapon system.

2. Statement of the Prior Art

In order to destroy a target or kill or injure enemy personnel using a sonic signal, it is necessary to vibrate the target at or near its resonant frequency. Since the resonant frequency of commonly encountered structural targets is relatively low, typically 5–20 hertz, a low frequency sonic beam is required. In addition, the sonic beam must have sufficient range to be effective as a weapon. While these two criteria are simple to state, they are not easy to implement. The reason is Rayleigh's Law which may be written in equation form as follows:

$$\delta = 1.22\,\lambda/\sin\phi$$

where

δ equals the radius of the central disc of energy,

λ equals the wavelength of the focused beam and

ϕ equals the angle subtended by the lens at the focal distance. For example, Rayleigh's Law predicts that the lens diameter required to focus a 10 hertz wave to within a 50 foot diameter zone of focus at a range of one mile is about 26,484 feet or about five miles.

Until recently, Rayleigh's Law was thought to be an absolute bar to the long-range propogation of a low frequency wave. Recently, however, it has been recognized that if two colinear sound beams are introduced into a nonlinear transmission medium, the interaction between them results in the production of the difference frequency. Thus, if the frequency of one of the beams is f and the frequency of the other beam is 2f, then the difference frequency component will also be f and may be used to augment the lower frequency sound beam. Moreover, the difference frequency component will have the range characteristics of the higher frequency component. However, this augmentation, commonly referred to as parametric pumping, will only take place if the phase difference between the two signals at the starting point of the interaction is approximately 90°. Otherwise, the component produced by the non-linear interaction will tend to oppose the lower frequency signal. The theoretical basis for these conclusions is set forth in an article by O. V. Rudenko and S. I. Soluyan entitled Theoretical Foundations of Nonlinear Acoustics (English translation) Consultant's Bureau, New York 1977, pp. 145–157. Applicant is not aware of any system which utilizes these principles to focus low frequency sonic signals over relatively large distances much less one that does so with sufficient power to destroy remote targets or kill or injure enemy personnel.

SUMMARY OF THE INVENTION

According to the present invention, I have developed a sonic weapon system which takes advantage of the interaction between colinear beams in a nonlinear medium to transmit low frequency sonic signals to remote targets, structural or human, with sufficient power to destroy them. The basic system includes a high level sonic source, means for separating the raw output from the sonic source into discrete frequency components, means for adjusting the phasing between these components and means for focusing them on the target.

The sonic source may comprise any sound source having a sufficient power output capacity to maintain destructive levels at the target and render the transmission medium, typically air, nonlinear. Commercially available jet and nuclear engines are sufficient for this purpose and their use is presently preferred.

Although nonlinear augmentation as between a fundamental signal frequency f and a pump signal frequency 2 f is known, it is desirable for weapon systems applications to provide still further augmentation. This may be effected by adding a second pump signal having a frequency (4 f) twice that of the first pump signal (2 f), a third pump signal (8 f) having a frequency twice that of the second pump signal (4 f), and so on. For the same reason and with the same effect that the 2 f pump signal augments the fundamental signal, the 4 f pump signal will augment the 2 f pump signal which, in turn, augments the fundamental signal. Similarly, the 8 f pump signal will augment the 4 f pump signal which augments the 2 f pump signal, and so on. As is the case between the 2 f pump signal and the fundamental signal, each successive pump signal must be 90° out of phase with the signal it augments.

The result is a low frequency sonic wave having the range characteristics of the highest frequency pump signal. The frequency of the highest frequency pump signal is, in turn, only limited by the expected losses due to divergence, sound absorption, transfer of energy to higher harmonics, etc. Based on these considerations, a maximum pump frequency of about 5,000 Hertz is presently preferred.

The frequency selector and phase controller serves to separate the raw output from the sonic source into the required fundamental and pump signal frequencies. The frequency selector and phase controller preferably comprises a combination of tubes, fans and masks. The input ends of the tubes are positioned to receive the raw output from the source such that the source output is distributed substantially equally among the tubes. A fan and a mask are disposed in the output end of each of the tubes, the mask being fixed relative to the tube.

The fan and mask in each tube are dimensioned such that as the fan rotates, it will alternately pass and block the flow of air through its corresponding tube. For example, a semicircular mask having a diameter equal to the internal diameter of the tube and a fan having a single matching semicircular blade are preferably used to generate the lower frequency components. Thus, as the blade rotates it will alternately pass through a position in which it is fully overlapped by the mask thus leaving half the output opening exposed, and a second position in which no portion of the blade is overlapped by the mask and the tube opening is fully blocked. This results in the generation of air pulses, the frequency of the pulses being dependent on the frequency of rotation of the fan blade. Since practical design limitations limit the maximum fan rotation speed, semicircular blades and masks will preferably not be used to generate the higher frequency components. According to the invention, this is overcome by adding additional mask sections and fan blades whereby each rotation of the fan blade results in the production of two or more pulses.

All the fans are preferably driven from a single rotating member through suitable gearing arrangements. The advantage of using a single rotating member, referred to herein as the fan speed controller, is that the fundamental and pump signal frequencies may be varied in step by simply varying the rotation rate of the controller.

Phasing is preferably accomplished by introducing a differential into the gearing for each fan. The differential permits each fan to be advanced or retarded relative to the others and thus may be used to control the relative timing and hence phase of the air pulses emanating from individual tubes.

The preferred sonic lens comprises a concave honeycomb array, each unit of the array comprising a hexagonal tubular structure closed at one end. By preselecting the cross-sections and lengths of the individual units, each unit may be tuned to enhance the reflection of a particular sonic frequency. Preferably, the array will have a number of honeycomb units tuned to each of the frequency components emanating from the frequency selector. Means are also preferably included for adjusting the pan and tilt of the individual honeycomb units whereby individual focusing of the honeycomb units may be effected. Also preferably included are means for adjusting the depth of each honeycomb unit relative to the others for fine tuning the phasing of the reflected signals.

The system is operated by focusing the output from the frequency selector and phase controller on the sonic lens and then focusing the sonic lens on the target. Upon activation of the source, the frequency selector will separate the raw output into discrete frequency components comprising a fundamental frequency at or near the resonant frequency of the target and successively higher pump frequencies. These components in turn strike the lens which then focuses them on the target. By selecting a sonic source with sufficient output to render the transmission medium nonlinear, the pump signals will augment the fundamental signal during transmission with the result being a high energy, low frequency sonic signal at the point of impact.

The destructive capability of the system during firing is maximized by adjusting the fan speed controller to match the fundamental frequency of the frequency selector and phase controller with the resonant frequency of the target. For this purpose, the preferred system also includes a laser interferometer for measuring the vibration frequency of the target. After appropriate signal conditioning, the information from the interferometer may be used to regulate the fan speed controller as required. Since accurate phasing is essential to effective operation, phasing is also preferably monitored during firing and adjusted as required. For example, signals from pressure sensors positioned to sense the amplitude peaks of each frequency component may be compared and this information used to implement phase control.

In one embodiment of the invention, level control of the individual frequency components is introduced by regulating the size of the opening to the individual tubes of the frequency selector. Portability may also be introduced as by using two flat bed trucks, one for the sound source and frequency selector and the other for the sonic lens and laser feedback system. The preferred embodiment also includes a computer for adjusting the various system parameters as required.

These as well as further features of the sonic weapon system according to the present invention will become more fully apparent from the following detailed description and annexed drawings of the preferred embodiment and suggested modifications thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. **1** is a diagrammatic illustration of the preferred parametrically pumped sonic weapon system according to the present invention;

FIG. **2A** is a partially diagrammatic side elevation of the preferred frequency selector and phase controller;

FIG. **2B** is a front elevation of the frequency selector and phase controller of FIG. **2A**;

FIG. **3A** is a front elevation of the tube **30***a* in FIG. **2** wherein the fan blade is positioned to pass air;

FIG. **3B** is a view similar to FIG. **3A** except that the fan blade is positioned to block air;

FIG. **4** is a front elevation of the preferred sonic lens;

FIG. **5** is a perspective view of one of the honeycomb units which make up the lens of FIG. **4**, the arrows indicating axes of motion;

FIG. **6** is a perspective view of the preferred sonic weapon system in operation;

FIG. **7** is a diagrammatic illustration of a computer system for regulating the operation of the preferred sonic weapon system;

FIG. **8** is a front elevation of the tubes **30***a* and **30***b* in FIG. **2B** showing an alternative means for effecting phase control; and

FIG. **9** is a front elevation of one of the tubes shown in FIG. **2B** illustrating an alternative means for generating high level, discrete frequency sound waves.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, FIG. **1** is a diagrammatic illustration of the preferred sonic weapon system **10** in accordance with the present invention. As shown, the system **10** includes a high intensity sound source **12**, a frequency selector and phase controller unit **14** for separating the source signal into preselected frequency components having predetermined phase relations, a sonic lens **16** for focusing the output signals from the unit **14** on a target **18**, and a laser feedback system **19** for detecting variations in the vibration frequency of the target **18** and using this information to adjust the output signals from the unit **14** to maximize the destructive capability of the system **10**.

The power output of the source **12** must be sufficient to destroy the target **18**. In addition, the sound pressure level of the source signal must be adequate to render the signal transmission medium nonlinear, since, as is discussed above, medium nonlinearity must exist for parametric pumping to take place. As will be apparent hereinafter, it is not absolutely necessary to rely solely on the intensity of the source signal to render the medium nonlinear. However, when the intensity of the signal form the sonic source **12** is relied on, it is estimated that for the frequency band of interest in an air medium, the nonlinear effect becomes significant at sound pressure levels of about 140 db. Since the intensity from the sonic source **12** required to destroy structural targets will generally be greater than 140 db, typically 160–190 db, a source **12** capable of destroying such targets will also be sufficient to render the air medium nonlinear. Various commercially available apparatus, such as rocket and nuclear engines, satisfy these criteria.

Before the design and construction of an appropriate frequency selector and phase controller **14** and sonic lens **16** may be implemented, it is necessary to know the approximate fundamental or base frequency, the approximate frequency of the highest frequency pump signal, the desired effective range of the sonic blast, the desired effective target area of the sonic blast on impact, the diameter of the sonic lens and, finally, the characteristics of the medium.

As is noted above, the destructive capability of the sonic weapon system **10** is maximized when energy transfer from the sonic blast to the target **18** takes place at the resonant frequency of the target. Since the resonant frequency of most structures is typically 5–20 hertz, a base or fundamental frequency of 5 hertz is desirable. Assuming the preferred air medium, a maximum pump signal frequency of about 5,000 hertz is presently preferred since at higher frequencies attenuation losses are so great that the contribution from any such signal would be insignificant. For weapons applications, a 50 feet diameter zone of focus at the point of impact is presently preferred. Referring to Rayleigh's equation above, and recognizing that sin $\phi \approx$ lens diameter/range for the ranges of interest, it is apparent that the diameter of the sonic lens **16** is directly dependent on the desired range of the weapon. When the desired portability of the system **10** is taken into account, a lens diameter of 50 feet is presently preferred. Solving Rayleigh's equation using these parameters yields an effective range of about 5,000 feet, which is considered strategically acceptable.

Referring now to FIG. **2**, the preferred frequency selector and phase controller **14** is shown. As illustrated, the unit **14** preferably comprises a plurality of tubular elements **30**, here shown to be eleven tubular elements **30***a*–**30***k*, each having a mask **32** and a fan **34** at one end **35** thereof, the masks and fans being unnumbered in the tubes **30***h*–**30***k* for purposes of clarity. The speed of the fans **34** is variably controlled by a fan speed controller **40** and, for reasons that will be more fully apparent hereinafter, the masks **32** are preferably fixed relative to the tubes **30**.

To accommodate the output of the sonic source **12**, it is presently contemplated that each of the tubular elements **30** will have a diameter of approximately 10 feet. Since the diameter at the output of an engine of the types contemplated for use as the source **12** is approximately 10 feet, the unmasked or input ends **36** of the tubular members **30** are preferably connected to the sonic source **12** by a frustoconical connecting member **38** which has its narrow end joined to the output of the sonic source **12** and its widened end joined to the input ends **36** of the tubular members **30**.

As discussed above, in order for the sonic weapon system **10** to be effective, the unit **14** must be capable of separating the raw output from the sonic source **12** into discrete frequency components comprising the fundamental frequency (5 hertz), a first pump signal having a frequency twice the base frequency (10 hertz), a second pump signal having a frequency twice that of the first pump signal (20 hertz), and additional pump signals, the frequency of each being twice that of the preceding pump signal, with the final pump signal having a frequency in the desired range, here selected to be about 5,000 hertz. In addition, augmentation of the fundamental frequency will not take place unless each frequency component is 90° out of phase with the next lowest frequency component. In other words, the 10 hertz pump signal must be 90° out of phase with the 5 hertz signal, the 20 hertz pump signal 90° out of phase with the 10 hertz pump signal, and so on. While the unit **14** could be designed to generate discrete frequency components having purely sinusoidal wave forms, this is not necessary. All that is necessary is that the selected wave forms have cyclical maxima which satisfy the specified frequency requirements. For example, sound pulses having a pulse repetition frequency meeting the above requirements would suffice. Accordingly, throughout the specification and claims, the term "frequency" is to be understood as the repetition rate of the selected wave form, whether it be sinusoidal, pulse, triangular, etc. The discrete frequency components at the output of each of the tubes comprising the unit **14** are best characterized as triangular waves. Referring to Table I below, the desired output frequencies of each of the eleven tubes **30***a*–**30***k* illustrated in FIG. **2** is shown wherein the 5 hertz output signal from the tube **30***a* represents the fundamental frequency and the 5,120 hertz output signal from the tube **30***k* represents the highest pump frequency.

TABLE I

Tube 30	Speed of Rotation in RPM's	Mask Sections	Output Frequency (hertz)
a	300	1	5
b	600	1	10
c	1,200	1	20
d	2,400	1	40
e	4,800	1	80
f	4,800	2	160
g	4,800	4	320
h	4,800	8	640
i	4,800	16	1,280
j	4,800	32	2,560
k	4,800	64	5,120

As may be best seen in FIG. 2B, the fans **34***a*–**34***e* disposed in the ends **35** of the tubular elements **30***a*–**30***e* each consists of a single semicircular blade **42**, the diameter of each blade **42** being equal to the internal diameter of its corresponding tube **30**. The masks **32** disposed in the ends **35** of the tubes **30***a*–**30***e* preferably each consist of a single mask section **43** of the same size and shape as the fan blades **42***a*–**42***e*. For purposes of clarity, only the fan blade **42***c* and mask section **43***c* are numbered in FIG. **2**.

Thus, as the blades **42***a*–**42***e* rotate, each will pass through a first position in which the blade **42** is fully overlapped by its corresponding mask section **43** (FIG. **3A**) and a second position in which there is no overlap between the blade **42** and its mask section **43** (FIG. **3B**). It will thus be apparent that in the first position half of the opening **44** is exposed while in the second position the opening **44** is completely blocked. Thus, as air is blown through the tubes **30***a*–**30***e* by the sonic source **12**, the masks **32***a*–**32***e* and fans **34***a*–**34***e* cooperate to alternately pass and block the exit of air through the openings **44** thus forming air pulses at the output of these tubes. Clearly, the frequency of these pulses depends on the speed of rotation of the fans **34** which, as already noted, is regulated by the fan speed controller **40**. Thus, if the fan **34***a* is rotated at 300 rpm, the frequency of the air pulses emanating from the end **35** of the tube **30***a* will be 5 hertz. Likewise, if the fan **34***b* is rotated at 600 rpm, the frequency of the air pulses emanating from the tube **30***b* will be 10 hertz. It will likewise be apparent that by successively doubling the speed of rotation of the fans **34***c*–**34***e* up to a maximum

speed of 4,800 rpm, the frequency of the air pulses emanating from the tubes **30***c*–**30***e* will be 20 hertz, 40 hertz, and 80 hertz, respectively. (See Table I.)

Because of anticipated design problems, it is not presently desirable to rotate any of the fans **34** at speeds above 4,800 rpm and, therefore, frequencies above 80 hertz cannot be generated by using semicircular masks and fans with increased fan speeds. In accordance with the present invention, this problem is preferably overcome by maintaining the speed of rotation of the fans **34** in the tubes **30***f*–**30***k* at 4,800 rpm while doubling the number of fan blades **42** and mask sections **43** in each successive tube. For example, referring again to FIG. **2**B, it may be seen that the fan **34***f* is comprised of two fan blades **42***f*, each blade comprising a quarter circle having a radius equal to the internal radius of the tube **30***f*. Likewise, the mask **32***f* is also comprised of two quarter-circle sections **43***f* each having a radius equal to the internal radius of the tube **30***f*. It will thus be apparent that during each rotation of the fan **34***f*, the baldes **42***f* will twice assume positions in which the mask sections **43***f* completely overlap the blades and twice assume positions in which no portion of the mask sections **43***f* overlap the fan blades **42***f*. Consequently, two air pulses will emanate from the tube **30***f* for each full rotation of the fan **34***f*. If, as is presently preferred, the speed of rotation of the fan blade **34***f* is 4,800 rpm, it will be apparent that the frequency of the pulses emanating from that tube will be 160 hertz (see Table I). By successively doubling the number of fan blades **42** and mask sections **43** in each of the remaining tubes **30***g*–**30***k* while maintaining the fan speed at 4,800 rpm, the frequency of the pulses emanating from these tubes will be 320 hertz, 640 hertz, 1,280 hertz, 2,560 hertz, 5,120 hertz, respectively (see Table I).

As noted above, rotation of the fans **34** is effected by the fan speed controller **40**. Controller **40** is, in turn, driven by an appropriate prime mover, the sonic source **12** being presently preferred. The rotational speed at the output of the controller **40** is preferably selected as 4,800 rpm to match the highest required fan speed, with rotation of the individual fans **34** preferably being accomplished through suitable gearing arrangements. Since the design and construction of a suitable fan speed controller **40** and suitable gearing arrangements are well within the capabilities of the skilled art worker, further descriptions thereof are deemed unnecessary and none are given. When fan speed control is effected on this basis, it will be apparent that the frequency of the output signals emanating from the unit **14** may be accurately controlled by varying the primary rotational speed of the fan speed controller **40** and that the required frequency ratios between the fundamental and pump signals will be maintained as the speed of the controller **40** is varied.

It is presently preferred that rotation be imparted to the fans **34** at their peripheries since the conventional approach of rotating the fans at their centers is complicated by the magnitude of the pressures involved. For example, the fan blades **42** of the fans **34** could be secured at their peripheries to the internal annular surface of an external annular gear supported for rotation in its corresponding tube by suitable bearings. As shown in FIG. **2**A, the masks **32** are preferably secured to the tubes **30** on the outward facing side of the fan **34** although they could, if desired, be disposed on the inward facing side as well.

While phase control can be introduced into the system **10** in a variety of ways, the preferred approach is to include a differential in the gearing for each tube fan **34**. Then, if a particular fan requires phase advance or retardation, the differential gearing for that fan may be adjusted as desired. Since the design and construction details of such differentials are well known to those skilled in the art, a further description thereof is deemed unnecessary and none is given.

To maintain the required 90° phase separation between the different frequency components generated by the unit **14**, pressure sensors **39** (FIG. **2**) are preferably disposed at the ends **35** of each of the tubes **30** such that the pressure changes resulting from the alternate blockage and passage of air through the tubes **30** may be sensed. (For purposes of clarity, the sensors **39** are not shown in tubes **30***j* and **30***k*). The time differential between pressure peaks for the different frequency components may then be compared to determine whether the desired 90° phase relation is present. The differential gearings to the fans **34** may be adjusted to correct any errors.

The unit **14** may also include means for regulating the levels of the signals emanating therefrom. This can be accomplished, for exanple, by introducing diaphragms at the inlet ends **36** of the tubes **30** following the example of diaphragms used in cameras to control the diameter of the lens opening.

Referring now to FIG. **4**, the preferred sonic lens **16** for focusing the signals emanating from the tubes **30** on the target **18** is shown. To be effective, the sonic lens **16** must be capable of focusing each of the different frequency components emanating from the unit **14**. In addition, the lens **16** will preferably also be capable of effecting fine control of the phasing amongst the reflected components.

As shown in FIG. **4**, the preferred sonic lens **16** comprises a concave honeycomb array. It may be seen in FIG. **5** that each unit of the array comprises a preferably hexagonal tubular structure **60** closed at one end **62**. Preferably, the cross-sectional area of the tubes and the tube lengths are adjusted to provide tuning of the discrete frequency components incident thereon, a preferably equal number of individual honeycombs **60** being tuned to each frequency.

As shown by the arrows in FIG. **5**, each honeycomb unit **60** is preferably supported for horizontal rotation (pan adjustment), vertical rotation (tilt adjustment) and front to back linear motion (depth adjustment). Pan and tilt adjustment of the individual honeycombs **60** gives the lens **16** the capability for individually focusing each honeycomb on the target **18**. A pan adjustment of $\pm 30°$ and tilt adjustment of $\pm 20°$ should be sufficient for this purpose. The depth adjustment permits fine phase adjustment of the discrete frequency components generated by the unit **14** by allowing the starting point of the nonlinear interaction between these components to be varied. The phase adjustment introduced by the front to back linear motion of the individual honeycomb units is, of course, in addition to the phase differential introduced by the differential gearing arrangements discussed above in connection with the unit **14**. Since it is contemplated that the depth adjustment of the individual honeycomb units will be used to effect fine phase adjustments only, and considering the relatively long wavelengths of the focused signals and the short travel distance between the unit **14** and the lens **16**, a front to back linear travel of ± 2 feet should be sufficient.

The phasing of the various frequency components reflected from the lens **16** may be checked by using pressure sensors **82** (FIG. **5**) similar to the pressure sensors **39** on the unit **14** (FIG. **2**). As shown in FIG. **5** the sensors **82** are preferably disposed at the open ends of each of the honeycomb units **60**. Again, these sensors serve to check phasing by measuring the time differential between pressure peaks for the different frequency components, any necessary adjustments being made by adjusting the relative depths of the tubes **60** in the array as is more fully discussed above.

Suitable arrangements for effecting pan, tilt and depth adjustments are well known to those skilled in the art and such arrangements may be used herein. For example, commercial grade movie cameras have this capability. On this basis, a further description of the means for adjusting the orientation of the individual honeycomb units **60** is deemed unnecessary. Suffice it to say that all connections will preferably be made to the backs **62** of the individual units **60**, the backs being selected solely on the basis of accessibility.

The sonic source **12**, frequency selector and phase controller **14** and sonic lens **16** may, by themselves, be effectively used as a sonic weapon and these three components comprise the basic embodiment of the present invention. However, as noted above, energy transfer from the system **10** to the target **18** is maximized when the fundamental frequency of the sonic blast is matched to the resonant frequency of the target **18**. Moreover, it must be recognized that as fissures, cracks, etc. begin to appear, the resonant frequency of the target may change. Therefore, and as shown in FIG. **1**, the preferred sonic weapon system **10** includes a laser feedback system **19** for continuously sensing the resonant frequency of the target **18**. The output signal from the system **19** is then used to adjust the fan speed controller **40** to match the fundamental frequency of the unit **14** to the resonant frequency of the target **18**.

As diagrammatically illustrated in FIG. **1**, the preferred laser feedback system **19** includes a laser **20**, an interferometer **22**, a frequency analyzer **24** and a band pass filter **26**. The output from the laser **20** is split. The first beam is directed at the target and reflected therefrom to the interferometer **22**, while the second beam is introduced directly into the interferometer. As is well known, by employing a photocell or similar device, the interferometer **22** can measure movement of the target **18** based on changes in the light pattern produced when the two laser beams are combined. Laser interferometers having sufficient resolution for incorporation in the sonic weapon system **10** are commercially available. For example, the Model 5526A laser interferometer marketed by Hewlett-Packard is capable of measuring distance with a resolution of one millionth of an inch. Also acceptable is Hewlett-Packard's Model 5501A which can measure distance with a resolution of six-ten-millionths of an inch. Based on preliminary estimates, this is at least a thousand times more accurate than is required for the system **10**.

While the range of these instruments, approximately 200 feet, is limited by the range of the lasers incorporated therein, their range can be increased by using a more powerful laser as, for example the Keuffel and Esser Rangemaster. The Rangemaster, which operates on a different principle than the lasers incorporated in the Hewlett-Packard interferometers, has a range of up to about forty miles.

The frequency analyzer **24** is, as shown, connected to the output of the interferometer **22** and serves to determine the frequency of motion of the structure based on variations in the light pattern resulting from interference of the two laser beams. Thus, the output of the frequency analyzer **24** is a signal indicative of the frequency of motion of the target **18**. Before applying this signal to the input of the fan speed controller **40**, it is desirable to filter the signal to reduce unwanted system noise. As presently preferred and shown, this is accomplished by using the band pass filter **26** which serves to eliminate frequencies outside the range of interest. Since the design and construction of frequency analyzers **24** and band pass filters **26** suitable for incorporation in the system **10** are well known to those skilled in the art, further descriptions thereof are deemed unnecessary.

The frequency of the laser beam directed to the target **18** is preferably chosen for maximum ability to penetrate haze, dust, and other atmospheric disturbances. Based on these consideration, a helium-neon laser, operating in the red portion of the visible spectrum, is presently preferred. To insure the accuracy necessary to obtain a meaningful signal at the output of the frequency analyzer **24**, the laser **20** and interferometer **22** should be kept as stationary as possible and isolated from ground vibrations. When designing the optical system, care should be taken to insure that only the light beam reflected from the target **18** can enter the interferometer **22**. This latter feature is a characteristic of commercially available laser interferometers such as those discussed hereinabove.

Referring now to FIG. **6**, the preferred sonic weapon system **10** together with means for transporting the weapon system to the target site are illustrated. As shown, the sonic source **12** and frequency selector and phase controller **14** are mounted on a first flatbed truck **80**. The sonic lens **16** and the laser feedback system **19** are mounted on a second flatbed truck **82**. The trucks will be driven to a site within the range of the sonic lens **16** and positioned such that the reflecting surface of the lens is directed at the target **18** and the unit **14** is directed at the lens but offset from the axis thereof. Accordingly, the assembly comprised of the source **12** and the unit **14** is preferably movably mounted on the flatbed truck **80** such that pan and tilt adjustments can be made. Likewise, the sonic lens **16** is also preferably movably mounted on the truck **82** for pan and tilt whereby the orientation of the lens may be adjusted. Since these pan and tilt adjustments may become defocused due to source vibrations during firing, means are preferably provided for monitoring them during firing and readjusting them as necessary.

Operation commences with the operator sighting the target **18** by using a sight **84** on the laser **20** provided for this purpose. The mechanisms for rotating and tilting the sonic lens **16** and for adjusting the relative orientations of the individual honeycomb units **60** thereof will preferably be operatively connected to track the laser **20** whereby sighting the target in the laser will simultaneously focus the lens. At or prior to this point, the laser feedback system **19** and the fan speed controller **40** are activated, the primary rotational speed of the controller **40** being initially selected to match the estimated resonant frequency of the target **18**. Firing is commenced by activating the source **12**.

As firing continues, the laser feedback system **19** senses variations in the resonant frequency of the target

18 and readjusts the speed of the controller **40** to vary the fundamental frequency of the unit **14** as required.

Preferably, the outputs from the pressure sensors **39** and **82** are also continuously monitored to insure that the desired 90° phase differential between successive frequency components prevails, the necessary adjustments being made on a continuous basis during firing.

It will be apparent from the foregoing that effective operation of the sonic weapon system **10** requires the continuous readjustment of a number of parameters. This, combined with the desirability of rapid readjustment for maximizing the destructive capability, dictates that the number of manual operations be minimized. Accordingly, it is presently preferred that the sonic weapon system **10** be computer controlled.

As diagrammatically illustrated in FIG. **7**, the computer **90** receives signals from the laser tracking mechanism, the laser feedback system **19**, and the pressure sensors **39** and **82**, and processes this information to provide output signals indicative of the adjustments required. After suitable conditioning, these output signals are used to adjust the physical orientation of the unit **14** relative to the sonic lens **16**; adjust the pan and tilt of the individual honeycomb units **60** for optimum focus; adjust the fan speed controller **40** to keep the system fundamental frequency in step with the resonant frequency of the target **18**; and adjust the differential gearings to the individual tube fans **34** and the depth of the units **60** to maintain 90° phasing. As shown in FIG. **7**, the computer **90** is also preferably connected to one or more output devices, such as the CRT **92**, for accommodating monitoring of system operation. The computer controller is also preferably connected to an input device, such as the terminal **94**, for feeding basic information, such as the target range and expected target resonant frequency into the computer, and for accommodating overrides when necessary. Since the design, implementation and programming of a suitable computer system for carrying out these functions is well within the capabilities of the skilled art worker once the method and parameters of the operation of the system **10** are known, further descriptions thereof are deemed unnecessary.

While computer control is preferred, the system **10** could be operated without the computer by having the operator monitor the signals which would otherwise be inputted to the computer and manually effect adjustment either directly or through appropriate mechanical-electronic/electrical controls. Most preferably, the system **10** will be provided with the capability for both computer and manual control to accommodate operation when the computer is down.

Preliminary calculations have been carried out based on the sonic weapon system **10** to assess its efficacy. These calculations assumed a power transmission efficiency of 30% based on expected losses from atmospheric attentuation, beam spreading, loss of energy to harmonics, etc. It was also assumed that the target structure consisted of a building $50\times50\times100$ feet high with four concrete walls one foot thick. For a resonant frequency of approximately 5 hertz, these calculations indicate that it will take approximately 13.2 seconds to destroy the entire structure, that approximately 11 gallons of jet fuel will be consumed, and that the required sound level at the target will be approximately 169 db. Similar calculations were carried out for a building $50\times50\times100$ feet high with walls two feet thick. Assuming a resonant frequency of 10 hertz, these calculations indicate that the entire structure could be destroyed in about 6.2 seconds, that approximately 84 gallons of jet fuel will be consumed and that the sound pressure level at the target must be about 181 db.

In addition to destroying structures, the weapon system **10** could be effectively utilized to selectively disable or kill enemy troops depending upon the sound level selected. Since troop disablement requires less power and higher frequencies, a system limited to this application could use a smaller lens and a less powerful sonic source. Apart from wartime applications, it will be apparent that the system **10** has peace time uses as well, building demolition being one example. If used for this purpose, the sonic source need not be as powerful as the source **12** required for the system **10** since the required transmission range is not as great.

Once the preferred sonic weapon system **10** described hereinabove is known, those skilled in the art will appreciate that various additions and modifications may be made thereto without departing from the spirit and scope of this invention. For example, while phase control of the unit **14** is preferably accomplished by employing differential gearing, this is not absolutely necessary. For example, phasing can be effected by adjusting the relative orientations of the masks **32** at the ends **35** of the tubes **30**. Thus, as shown in FIG. **8** for the case of the tubes **30***a* and **30***b*, by rotating the mask **32***b* one quarter turn relative to the mask **32***a*, it will be apparent that the signal exiting the tube **32***a* will lead the signal exiting the tube **32***b* by 90°. It will be further apparent that by rotating each successive mask **32***c*–**32***k* one quarter turn relative to the preceding one, each frequency component exiting the unit **14** will lag the next lower one by 90° and the desired phasing will have been achieved.

In a further modification of the unit **14**, the conventional fans **34** illustrated in FIG. **2** are replaced with fans having blades which push air in both directions. When this embodiment is used, a separate sound source such as the sonic source **12** would not be used and fan blades **42** would themselves generate sound. For example, as shown in FIG. **9**, the fan **100** could be substituted for the fans **34** used to generate the five low frequency components in FIG. **2**. As shown, half of the fan **100** has blades **102** oriented for pushing air in one direction while the other half **104** are oriented for pushing air in the reverse direction. It will be apparent from FIG. **9** that the fan blades **102** and **104** contribute to the air flow as they come out from behind the mask **32**. For example, if all the blades which push air forward are exposed at one time there would be a maximum forward thrust of air. As the fan rotated, there would be a combination of both forward and reverse blades exposed which would slow the forward thrust. At a still later point, only those blades which were pushing air in the reverse direction would be exposed. The principal advantage of this approach is that the resulting sound pressure waves will be approximately triangular in shape and thus will more closely approximate sinusoidal air flow. When this modification is employed, energy input could be derived, for example, from the source utilized as the sound source **12** in the FIG. **1** embodiment, the only difference being that the source now serves to rotate the fan blades. The arrangement illustrated in FIG. **9** may be utilized to generate the higher frequency components by adding additional opposed blade sections, the number of opposed blade sections required being equal to the number of mask sections required in the FIG. **2** embodiment as

set forth in Table I. Phasing of a plurality of fans **100** could be introduced by differential gearing, relative rotation of the masks, or any other suitable techniques.

The FIG. **9** embodiment may be further modified by providing fan blades and masks at both ends of the tube. This arrangement would be more truly resonant than those discussed above with the length and cross-section of the tube and the phasing of the fan blades and masks providing highly selective sound filtering and sound generation capabilities.

As noted above, it is not necessary to rely solely on the intensity of the sound generated by the sonic source **12** to render the transmission medium, typically air, nonlinear. Thus, for example, the transmission medium may be rendered nonlinear or its nonlinearity enhanced by periodically introducing shock waves along the transmission path. Such shock waves, which are familiar when a body passes through air at supersonic speeds or highly compressed air is suddenly released, result in a rapid rise in pressure that is propagated through the medium. It is presently contemplated that such shock waves will be used to enhance the nonlinearity of the air medium by introducing them into the transmission path in synchronization with the fundamental frequency of the system **10**. Since, as is discussed above, the conversion efficiency obtainable by nonlinear parametric pumping is dependent on medium nonlinearity, enhancing the nonlinearity of the medium will increase the overall efficiency of the system **10**.

Still further changes and modifications may be made. For example, while the tubes **60** which make up the lens **16** have been described as having preferably hexagonal cross-sections, this is not necessary and other cross-sectional configurations, such as circular cross-sections, may be substituted. In any event, because of the high sonic levels and numerous moving parts, aerospace design techniques will preferably be employed throughout.

Since these as well as further changes and modifications may be made within the scope of the present invention, the above description should be construed as illustrative and not in a limiting sense, the scope of the invention being defined by the following claims.

I claim:

1. A system for transmitting a parametrically pumped sonic signal through a transmission medium to a remote location comprising:

a sound source

means for separating the sound from said source into a plurality of discrete frequency components including a fundamental component and at least one additional component, each additional component having a frequency twice that of the next lowest frequency component;

means for adjusting the phase difference between each frequency component and the next lowest frequency component to substantially 90°;

means for colinearly focusing said components on said remote location; and

means for rendering said transmission medium nonlinear between said focusing means and said remote location.

2. The system of claim **1**, wherein said signal separating means comprises:

a plurality of frequency selective elements, each comprising:

(a) a tubular structure defining a longitudinal passage communicating with an inlet end and an outlet end;

(b) means disposed in said tubular structure for obstructing a portion of said passage; and

(c) means movably disposed in said tubular structure for alternately exposing and blocking the remainder of said passage; and

means for controlling the time lapse between exposures of said remainders of said passages.

3. The system of claim **1**, wherein said means for rendering said medium nonlinear comprises said sound source.

4. The system of claim **1**, wherein said means for rendering said medium nonlinear comprises means for generating shock waves and introducing said shock waves into said transmission medium at said fundamental frequency.

5. The system of claim **1**,

wherein said remote location comprises an object; and

further comprising:

(a) means for sensing the vibration frequency of said object and for generating an output signal indicative thereof; and

(b) means responsive to said output signal for adjusting the frequency of said fundamental frequency component to match the vibration frequency of said object and for adjusting the frequencies of said additional frequency components for maintaining each additional component at twice the frequency of the next lowest frequency component.

6. The system of claim **1**, and

further comprising means for sensing the phase difference between said frequency components and for generating an output signal indicative thereof; and

wherein said phase difference adjusting means is responsive to said output signal.

7. The system of claim **2**, wherein said obstructing means comprises a mask and said movable means comprises a fan.

8. The system of claim **2**, wherein:

said sound source comprises an engine; and

each of said inlet ends is oriented to receive a portion of the sound from said engine and said output ends are oriented to direct sound entering said inlet ends to said focusing means.

9. The system of claim **1**, wherein said focusing means comprises a plurality of tubular structures each defining a longitudinal passage having a closed end and an open end, said open ends being oriented to receive the sound output from said separating means.

10. The system of claim **2**, and further comprising means for regulating said controlling means for varying the frequency of said fundamental frequency component and for adjusting the frequencies of said additional frequency components for maintaining each additional component at twice the frequency of the next lowest frequency component.

11. The system of claim **2**, and

further comprising means for sensing the phase difference between said frequency components and for generating an output signal indicative thereof; and

wherein said adjustment means are responsive to said output signal.

12. The system of claim **3**, wherein said means for rendering said medium nonlinear further comprises

means for generating shock waves and introducing said shock waves into said transmission medium at said fundamental frequency.

13. The system of claim 5, wherein said vibration frequency sensing means comprises a laser interferometer.

14. The system of claim 7, wherein said controlling means comprises means for rotating said fans at different speeds.

15. The system of claim 7, wherein said controlling means comprises:

means for rotating said fans; and

each of said masks and said fans having different numbers of sections and blades, respectively.

16. The system of claim 7, wherein:

said sound source comprises said fans; and

each fan comprises a segment including a blade for pushing air towards said outlet opening and a blade for pushing air away from said outlet opening.

17. The system of claim 7, wherein said phase difference adjustment means comprises each mask being rotated an amount equal to a 90° phase difference relative to the mask in the tubular structure corresponding to the next lowest frequency component.

18. The system of claim 9, wherein said focusing means further comprises means for adjusting the pan and tilt of each of said tubular structures.

19. The system of claim 9, wherein said phase difference adjusting means includes means for adjusting the depth of each tubular structure relative to the depth of the other tubular structures.

20. The system of claim 9, wherein the dimensions of said passages are preselected to enhance the reflection of said frequency components.

21. The system of claim 10,

wherein said remote location comprises an object;

further comprising means for sensing the vibration frequency of said object and for generating an output signal indicative thereof; and

wherein said regulating means is responsive to said output signal for matching said fundamental frequency to said vibration frequency.

22. The system of claim 11, wherein said sensing means comprises pressure transducers disposed at the output ends of said tubular structures.

23. The system of claim 14, wherein said controlling means further comprises the mask and fan in at least one of said tubular structures having a different number of sections and blades, respectively, than the mask and fan in at least one other tubular structure.

24. The system of claim 14, wherein said fan speed controlling means comprises a rotating member and gearing means connected to said rotating member and said fans for rotating said fans upon rotation of said rotating member.

25. The system of claim 15, wherein the number of mask sections in each tubular structure is equal to the number of fan blades in that tubular structure.

26. The system of claim 16, wherein said controlling means comprises means for rotating said fans at different speeds.

27. The system of claim 16, wherein said controlling means comprises:

said fans having different numbers of segments; and

means for rotating said fans.

28. The system of claim 16, wherein said masks and fans are disposed at the outlet ends of their respective tubular structures.

29. The system of claim 19, and

further comprising means for sensing the phase difference between said frequency components at the open ends of said tubular structures and for generating an output signal indicative thereof; and

wherein said depth adjusting means is responsive to said output signal.

30. The system of claim 20, wherein a plurality of tubular structures enhance the reflection of each frequency component.

31. The system of claim 23, wherein the number of mask sections in each tubular structure is equal to the number of fan blades in that tubular structure.

32. The system of claim 24, wherein said phase difference adjustment means comprises a differential in said gearing means for each fan.

33. The system of claim 26, wherein said controlling means further comprises at least one of said fans having a different number of segments than at least one other fan.

34. The system of claim 28, and further comprising additional masks and fans disposed at the inlet ends of said tubular structures.

35. The system of claim 29, wherein said sensing means comprises pressure transducers disposed in the output ends of said tubular structures.

36. The system of claim 1, further comprising means for regulating the amplitude of said components.

* * * * *